Creation of a Power Supply on a Breadboard Using Common Electronics Components (December 2018)

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***Abstract*—A DC power supply was created using common electronics components. The power supply used a standard American line voltage as the input, and after stepping down the voltage in a transformer, three different topologies – a full wave rectifier, a linear regulator, and an amplifier – were used to ensure a constant output voltage of 5 – 10 volts, with a current of at least 0.5 milliamps regardless of the load resistance used. The circuit was successfully constructed on a breadboard, and was modeled using LTSpice CAD software. In order to accurately model the circuit in LTSpice, a custom transistor had to be programmed for the NTE2312 NPN transistor used in the circuit.**

***Index Terms*—LTSpice, Power Supply,**

I. Introduction

POWER supplies are used in most daily electronics. Everything from personal computers to desk lamps requires a steady and predictable supply of electricity in order to function properly. In the United States the standard amount of electricity drawn from a wall outlet is an AC voltage source at 120 volts RMS, with a frequency of 60 Hz. In order to safely supply the needed electricity without damaging the internal components or causing death/injury to a human operator, a power supply must take the line voltage and current then convert it down to a level that is safer for use.

II. Device Description

A simple power supply with an externally adjustable output voltage between 5 to 10 volts with a DC current of at least 0.5 amperes was designed and assembled on a standard breadboard using common circuit components including capacitors, transistors, and diodes. All resistors used in the circuit were power resistors rated to 10 watts, with the exception of a 100kΩ resistor used to ground the op-amp which was rated to 2 watts. A single LM 741op-amp manufactured by Texas Instruments was used in the construction of this power supply. A complete list of components used can be seen in table 1. This device is intended to have any load resistor applied, while maintaining a guaranteed range of voltages (between 5-10 volts) and a current not to exceed 0.5 amps.

TABLE 1
COMPONENTS USED IN THE CONSTRUCTED POWER SUPPLY

Part	Manufacturer	Quantity
µA741CP Op-Amp	Texas Instruments	1
100kΩ Power Resistor (2 Watt)	NTE Electronics	1
10kΩ Power Resistor (10 Watt)	NTE Electronics	1
1000Ω Resistors (0.25 Watt)	ELEGOO	4
10Ω Power Resistor (10 Watt)	NTE Electronics	1
1.0Ω Power Resistor (10 Watt)	NTE Electronics	1
1N4001 Power Blocking Diode	ON Semiconductor	4
1Ω Power Resistor (10 Watt)	NTE Electronics	1
3300µF Capacitor	Jackcon	1
2200µF Capacitor	Jackcon	1
CT6EP103-ND 10kΩ Potentiometer	Digikey	1
IEC320 C14 Male Power Socket With 5A Fuse	URBEST	1
NEMA 5-15P to IEC320C13 Power Cord	AmazonBasics	1
NTE2312 Silicon NPN Transistor	NTE Electronics	2
NTE5119A Zener Diode	NTE Electronics	1
TR212 12 Volt AC 2.0 A Transformer	Philmore	1

A. Full Wave Rectifier

The full wave rectifier is constructed of four diodes which ensures that the input voltage never drops below zero[1]. Functionally, this converts an AC current to a DC current. The diodes are arranged in such a way that the alternating current going across the diodes must always cross alternating diodes prior to entering the circuit. Because diodes do not allow for current to flow in the reverse direction, this guarantees that the current will only follow one path into the circuit.

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Fig. 1-Block diagram outlining the topologies involved in this circuit.

B. *Linear Regulator*

The linear regulator was constructed using a capacitor and a resistor in parallel. At this point in the circuit, the voltage has been converted from AC to DC, but still moves from zero to the peak voltage. In order to provide a constant voltage, a linear regulator needed to be introduced. This linear regulator was constructed with a 3300µF capacitor and a 10kΩ resistor. After the current leaves the linear regulator, a small ripple is still present, but it is constrained to a 1.3-volt variation[2].

C. *Amplifier*

The amplifier was constructed using a Zener diode, general purpose op-amp, and two transistors. The connection of the Zener diode to the non-inverting input of the op amp ensures a constant voltage across the terminals, this is called a shunt regulator which is a type of linear regulator[2]. The inverting input of the op-amp is connected to ground through a 10kΩ potentiometer, and connected to the output voltage through a 4kΩ resistor. The positive rail voltage was connected to the C terminal of the transistor connected to the output voltage. The negative rail voltage of the op-amp was connected to ground.

III. Results

A circuit was constructed using the components listed in Table 1. The entire circuit was connected to a wall outlet using an 18 AWG power cable and connected to the circuit through a power socket containing an on/off switch and fuse. The input voltage measured after the voltage transformer was determined to be 14.7 V_{RMS}. When the power was turned on, the circuit was measured to have an output voltage of 6.0 volts, and an output current of 80 – 240 mV.

A. *Constructed Circuit*

The 5500µF capacitor was constructed out of two smaller capacitors in parallel – a 3300µF and 2200µF capacitor. The 4000Ω resistor was made out of a functional equivalent of four 1000Ω resistors. The circuit was connected to ground via a DC power supply's ground socket. A 10Ω resistor was used for the circuit's load resistance. The input voltage to the op-amp's non-inverting input was measured with a DMM and found to be 5.9 volts, while the inverting input was measured at 4.2 volts. The positive rail voltage (from the Vin node) was found to be 16.7 volts using the same method. The output voltage from the op-amp was measured to be 7.0 volts.

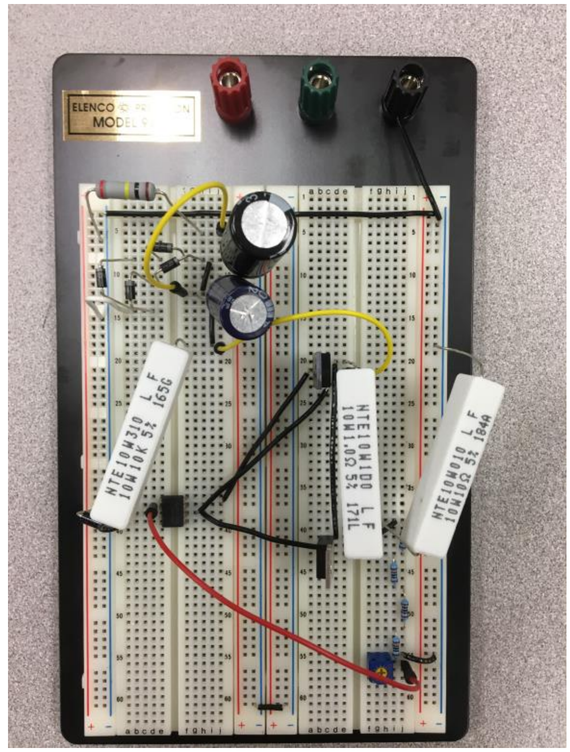

Fig. 2-Circuit which was constructed to create the power supply.

B. *NTE2312 Transistor in LTSpice*

LTSpice CAD software was used to simulate the results of the circuit. In order to accurately simulate the circuit, a new NPN must be added to the BJT library that is lacking in LTSpice after installation on a personal computer. The values for IKF, CJC, CJE, TF, VCEO, and Icrating were either estimated, calculated, or taken directly from the datasheet, however the values for IS, VAF, BF, XTB, BR, TR, ITF, VTF, XTF, RB, RC, and Vceo used the default parameters.

```
.model NTE2312 NPN (IS=1E-14 VAF=100
+  BF=60 IKF=0.3 XTB=0 BR=1.0
+  CJC=55E-12 CJE=55E-12 TR=1E-8 TF=3.98e-8
+  ITF=0 VTF=2 XTF=0 RB=0 RC=0 Vceo=400
   Icrating = 8 mfg=NTE)
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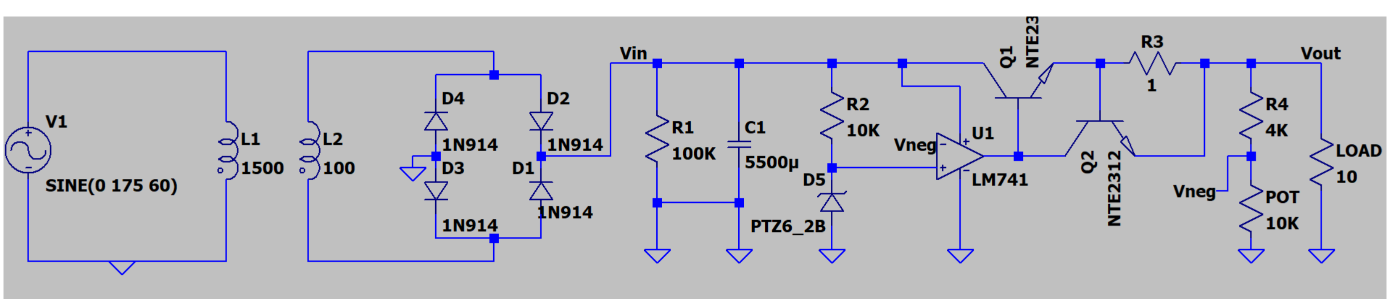

Fig. 3-Schematic of the circuit that was constructed

C. *Simulations in LTSpice*

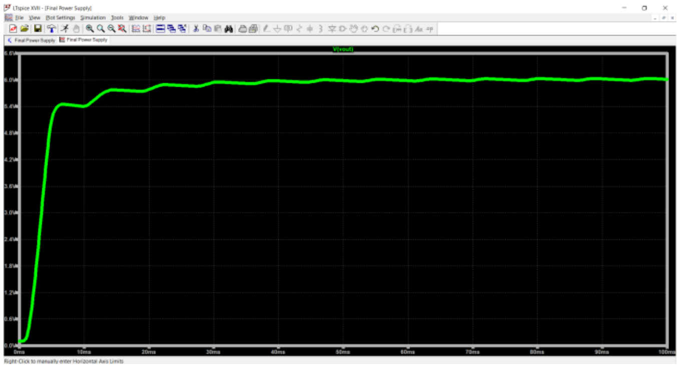

Fig. 4-The Spice simulation demonstrated an output voltage of about 6.0 with a 39mV ripple, this is very similar to my measured value of 6.0 volts. The ripple is likely due to approximations used when programing the NTE2312 transistor.

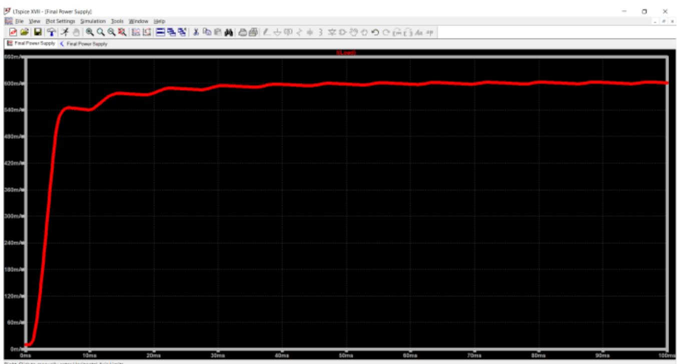

Fig. 5-The Spice simulation revealed a constant current of 600mA, with a 3.9mA ripple.

D. *Load Resistance and Voltage*

Different load resistances will result in different potential differences across them. The higher the load resistance is, the higher the voltage will become until it asymptotically reaches a maximum voltage of 10 volts. Two different load resistances were tested, a 10Ω and 10KΩ resistor were used.

TABLE 2
LOAD RESISTANCES AND OUTPUT VOLTAGE

Load Resistance	Output Voltage
10Ω	6.00 Volts
10,000Ω	8.50 Volts

IV. Discussion

The power supply that was built in in this project needed three distinct topologies in order to work as intended. A full wave rectifier was first used after voltage transformation to create a DC input. The next step involved creating a linear regulator using a resistor and capacitor in parallel, along with a Zener diode before the non-inverting input of the op amp to ensure a constant input voltage to the op-amp. Finally, the amplifier used in conjunction with the two transistors ensured an appropriate output voltage and current.

The design of this power supply was not able to adjust the output voltage with the potentiometer, and this error was also replicated in the Spice simulations. This is likely due to the placement of the potentiometer within the circuit. Because the Zener diode in the linear regulator has the largest effect on the output voltage by way of effecting the input voltage at the non-inverting input, placing a potentiometer leading into the Zener diode instead of a fixed 10KΩ resistor may have had a more noticeable effect on the output voltage.

The Spice simulation's output waveform for both current and voltage had a slight ripple while the measured voltage appeared to be a constant DC voltage. The ripple in the simulation is likely due to using several approximate and default values rather than calculating out the exact necessary values for each parameter. Nonetheless, the model proved to be accurate enough to give an acceptable approximation for modeling purposes.

This design would likely benefit by further refining the model used for the transistor, and making the output voltage adjustable through the potentiometer. Furthermore, the design could likely be improved by substituting an integrated bridge rectifier rather than constructing the piece out of four diodes. Finally, for purposes of creating a prototype circuit, most resistors used power resistors; to decrease the cost of production in the future, regular 0.25-watt resistors could be substituted in the linear regulator.

V. Conclusion

A power supply that met the outlined parameters was successfully constructed, sans an adjustable voltage output dependent on a potentiometer. This project also utilized the programming of a custom transistor in LTSpice using information provided in the component's datasheet. The transistor was neither packaged with the LTSpice software nor was it readily available online. It was written accurately enough to be able to model the circuit with simulation software.

References

[1] A. Sedra, K. Smith "Diodes," in *Microelectronic Circuits*, 7th ed. New York.

[2] A. Malvino, "Regulated Power Supplies," in *Electronic Principles, 8*th ed. New York.

Michael C. Hernandez was born in Portland, OR in 1991. He graduated Cum Laude from Portland State University with a bachelor's degree in organismal biology and a minor in chemistry in 2014. He is currently pursuing a second bachelor's degree in electrical engineering at Oregon Institute of Technology in Wilsonville, OR after retiring from his studies at Western University's College of Osteopathic Medicine of the Pacific – Northwest's DO program.

Michael has presented a research poster at the Oregon Museum of Science and Industry (OMSI) in 2013 on the physics behind the Ethicon's ultrasonic harmonic scalpel used in laparoscopic surgery. He has also mentored numerous students as an organic chemistry and physics workshop leader. In 2012 he worked with physics graduate student (now Ph.D.) Justin Dunlap in developing teaching laboratory experiments for introductory physics courses designed to teach simple harmonic motion by modeling a person's walking gait using Vernier software. Throughout the duration of the 2013-2014 school year he conducted molecular biology research with the Courcelle laboratory at Portland State University developing genetically modified *e. coli* bacteria designed to selectively degrade target proteins when exposed to lactose. He also is affiliated with the Clackamas Volunteers in Medicine primary care clinic, training medical scribes in the use of electronic medical records software to maintain accurate records of patient encounters with volunteer physicians for low income patients.